TRUSS BRIDGE PROJECT

Demonstration: Tuesday, Dec. 5, 6:00 pm, Allan Hancock College, Room TBA

1. ASSIGNMENT

1.1. **Working as a team, design and demonstrate a truss bridge at 6:00 pm on Tues., Dec. 5, 2017 at Allan Hancock College, Santa Maria, CA, Room TBA.**
Each team will consist of two–four members. *Ideally*, each group will consist of three members. In no case shall a team have more than four members. As needed, some teams may have two members. In no case shall a team have less than two members.

1.2. **Turn in a timeline for the project** at **6:00 pm Thurs., Nov. 9**, with at least 2 sketches of potential designs, listing pros and cons for each.

1.3. Write a **team** engineering report as described below. The report will be due at **6:00 pm, Thurs., Dec. 7, 2017**.

1.4. Each **individual** will submit a confidential and individual evaluation of his/her team and its members, due at **4:00 pm, Thurs., Dec. 14, 2017**. Evaluation forms will be made available on the course website and/or in class. "Confidential" means you are not supposed to work with/show it to anyone else (including your team members).

1.5. The primary educational goal/objective of this assignment is to **work together** as a team in a design exercise. Doing so requires effective communication, open sharing of ideas, group time-management skills, and fair distribution of work-load (taking on enough, but not dominating the team). While each team member may not be the primary person responsible for a certain part of the work, each member should be involved in each piece, and will be held responsible for the entirety of what the group turns in.

2. PROJECT GOALS and OBJECTIVES

In terms of the project itself, the goals and objectives of the project include:

2.1. to **design and build a truss bridge that meets the requirements, using the limited amount of basswood and glue provided**;

2.2. to create a timeline to help schedule the various stages of your project (brainstorming, rough analysis, decision, detailed analysis, construction, report writing). Such a schedule is often made with a Gantt Chart. The timeline for the project is due at **6:00 pm, Thurs, Nov. 9 along with a sketch of two possible designs**, listing pros and cons for each (you can start on the project before then).

2.3. to demonstrate the bridge, under the prescribed load conditions.

2.4. to **write a brief engineering report** (see details in ***Section 7***) that:

2.4.1. describes the purpose of the project and the evolution of the design;

2.4.2. describes the final design, including a dimensioned engineering drawing (e.g., a CAD drawing or a good hand-drawing), and a cost analysis;

2.4.3. **analyzes all the forces in each plane truss** when the bridge is subjected to a concentrated force, W, at the bottom-center joint of each plane truss ($2W$ total load on the bridge);

2.4.4. reports the results of the load-demonstration and provides recommendations.

2.5. to design and build a truss that will support the largest possible load at its center without failing, and/or has the greatest *load efficiency* (load-to-weight ratio).

2.6. Prior to building, each team should generate design sketches/ideas of at least 3 different bridge designs (style, geometry, size, etc.). These sketches are to be included in the appendix of the final report.

3. MATERIALS (per team)

3.1. **44 pieces of 3/32″×3/32″ basswood**, **12″ long** (*provided by customer/instructor*);

3.2. **2 bottles of white tacky glue** to join the members (glue *provided*). No other glue is permitted.

3.3. **gussets** (*provided*) of 1/16″-thick basswood to join the members. The gussets may be no wider than, nor taller than, 1/2″. Four (4) 12-inch long pieces will be provided.

Note: Joints (connections) are critical parts of a structural system. Gussets transfer load from one truss member to another. See *Figure 4/1* of the textbook for examples of gussets.

3.4. Tools: **graph paper** (large), **pins**, **EasyCutter, insulation board, wax paper**. All *provided*.

3.5. The truss members may not be laminated (gluing two or more pieces together along their length).

3.6. Only one member may span between any two joints; truss members may not be "doubled-up" between joints.

3.7. No part of the bridge may be painted or treated in any way to change its strength or appearance.

4. DESIGN SPECIFICATIONS

4.1. Overall Structure

4.1.1. The bridge will be made of two identical plane trusses, set parallel to each other. The bridge must be constructed with the materials provided.

4.1.2. The plane trusses shall be connected by cross-beams between corresponding joints of each truss, and by diagonal members to prevent collapse of the bridge (by the plane trusses moving parallel to each other). The cross-beams and diagonals are to be made using the 3/32″×3/32″ basswood material provided. The lower cross-members would support a roadway. *DO NOT construct a roadway.*

4.1.3. Each truss will be either a *Howe Bridge Truss* or a *Pratt Bridge Truss* (see ***Figure 1***). The lengths of the truss members are to be determined by the design team, but in no case shall the joints be less than 3.0″ (i.e., between points where the center-lines of the members meet; approximately the distance between gusset-centers).

4.1.4. **ALTERNATE DESIGNS** (other than the Howe or Pratt), **must be *pre-approved by the customer*. Deadline for alternate design submission is: 9:00 pm, Tues., Nov. 14, 2017.**

4.2. Dimensions (see *Figure 2*)

4.2.1. The bridge must span an 18″-wide valley (two tables placed 18″ apart). The end (support) joints of the bridge will be a minimum of 1″ from the cliff of the valley. **Thus, the bridge itself must be <u>at least 20″ long</u> from lower support-joint-to-support-joint.**

4.2.2. Each truss may be <u>no taller than 8″</u> (as measured between *centerlines* of the top-most and bottom-most truss members (i.e., the upper and lower chords of the plane truss). Thus each truss may be at most 8-3/32″ tall, not counting gussets and cross members connecting the two plane trusses.

4.2.3. The bridge (outer dimension) must be <u>at least 4″ wide</u>.

4.2.4. The roadway (inside dimension of the bridge) must be <u>at least 3″ wide</u>.

4.2.5. There must be <u>at least a 3″ clearance above the entire width of the "roadway"</u> along the entire length of the bridge (you cannot block the road).

4.2.6. Each team may only use the amount of basswood provided (a maximum of 44 pieces of 3/32″×3/32″ basswood, 12″ long) to construct the bridge.

4.2.7. Gussets may be no wider nor taller than 1/2″.

4.2.8. The center-to-center gusset distance must be no less than 3.0″.

4.3. Supports (see *Figure 3*)

4.3.1. During testing, the bridge will be supported at each end by 2×4s, one on top of each table. The supports may be placed anywhere on the tables, but may not hang over the table edge.

4.3.2. The lower joint at the end of each truss may be no less than 1″ (horizontally) from the cliff (table edge), and no more than 1″ from the edge of the 2×4 support (nearest the table edge).

4.4. Load (see *Figure 3*)

4.4.1. The applied load will be $2W$, applied at the center of the bridge, at the bottom-center joints. Each plane truss will thus support point load W at its bottom-center joint.

4.4.2. Applying the Load

4.4.2.1. The *customer* (instructor) will provide two strong structural members (metal bars), 6″-long, with square cross-section 3/32″×3/32″, over which a wire rope (cable) is slung to apply the load – a bucket of sand (or similar) hanging from the wire rope.

4.4.2.2. The design team is responsible for *temporarily** accommodating <u>both</u> of these bars into the bridge in order to apply the load. The bars are to be placed horizontally, and set perpendicular to the "roadway," and be supported on the truss-members on either side of the bottom-center joint (gusset) of each truss.

**Temporarily*: at least during testing.

4.4.2.3. The bars are to rest on the bottom center members of each truss within 1/2″ of the bottom-center joint. No reinforcing structure to set the bars on is allowed.

4.4.2.4. The bars must have a clear horizontal length of 3″ (e.g., the roadway width) over which the wire rope may be slung. This wire rope will carry the applied load.

4.4.2.5. The weight of the metal bars and wire rope will <u>not</u> be included in the weight of the bridge. The metal pieces will be included in the load.

4.5. Costs

4.5.1. Costs will be taken into account. The costs will be based on the total length of members used, and the total number of gussets used.

4.5.1.1. Each inch of the model bridge is assumed to cost $1,000.

4.5.1.2. Each gusset is assumed to cost $6,000 due to the labor costs associated with making the connection.

5. BUILDING RECOMMENDATIONS

5.1. Use gussets (see ***Figure 4***).

5.2. Cut the basswood with the EasyCutter (*provided*). Breaking them with your hands creates ragged ends.

5.3. Cut diagonal members at an angle so that they fit solidly at the juncture of the vertical and horizontal members (see ***Figure 4***).

5.4. Consider out-of-plane and twisting stability of the bridge. Provide sufficient cross-bracing (perpendicular and diagonal bracing) between trusses to resist collapsing and twisting.

5.5. To construct each truss, draw it (full scale) on large graph paper (*provided*). An additional 8.5×11″ piece of paper (graph/engineering) may be required for the entire length of the bridge. Lay the insulation board (*provided*) on a table; the board should be thick enough to accommodate the pins (*provided*) used to hold the truss members in place as each truss is constructed. On the insulation board, place the full scale drawing on the graph paper and tape it down. Lay wax paper over the graph paper, and tape it down. Lay the wooden truss members on the wax paper over the drawing. Hold the members with the pins. Glue the members together using gussets.
The wax paper is used to protect your original full-scale drawing from the glue, etc.

5.6. A single physical member may be connected to more than 2 gussets; i.e., a member may continue through a gusseted joint (see ***Figure 5a***). However, only one member may span between any two gussets/joints. Members may not be laminated to form one "double" member (see ***Figure 5b,c***).

5.7. Set glue to try at least 2 days prior to testing.

6. DEMONSTRATION

6.1. Bridges will be demonstrated **at 6:00 pm on Tues., Dec. 5, at Allan Hancock College, Room TBA.**

6.2. Bridges will be weighed and measured before being subjected to load.

6.3. Before loading, each team will be asked to predict where failure of the bridge will likely occur.

6.4. Bridges will be loaded at the bottom-center joint of each truss with an increasing load (e.g., a bucket of sand) until failure occurs.

6.5. The load at failure – when the bridge collapses or otherwise can no longer support its load – will be recorded.

6.6. At the demonstration, the bridges will be ranked based on the following criteria:

6.6.1. *Maximum Load* carried, and

6.6.2. *Load Efficiency*: Load per Unit Weight of the Bridge.

7. REPORT

7.1. Each group will submit a single report. The report should be simply stapled (no fancy cover, folder, etc.).

7.2. The report should be typed, and include the following:

7.2.1. Title page.

7.2.2. Table of Contents (Section titles and page numbers).

7.2.3. An Introduction, which describes the goals/objectives of the project, i.e., the purpose of the design/what the design is supposed to do (since this to be an engineering reports, the purpose of the project is not "to learn" …even though you are learning).

7.2.4. A narrative of the evolution of the bridge design.

7.2.5. Drawings (CAD drawings or very good hand-drawings) of the ***final truss design***. The drawings should include the ***side view*** of bridge; i.e., the plane truss. Only one plane truss needs to be shown since they are identical. Additional drawings must include the ***top view*** of the bridge, showing the cross-bracing system, as well as the ***end-view*** (along the road-way).
The drawings are to be ***to scale*** and show all necessary dimensions. Note that "to scale" does not mean a *full-size* drawing.

7.2.6. Analyze the plane truss with a load *W* applied at the bottom-center joint of a single truss (*W* is half of the total load since there are two plane trusses). **Predict all forces in each member in terms of load *W*.**
*Note that truss systems are usually symmetric about the center of the truss. When the applied load and supports are symmetric, only one half of the truss need be solved (internal forces are symmetric).

7.2.7. Indicate any assumptions made in analyzing the problem.

7.2.8. Report which element the team predicted would fail first. Explain why. Consider both tension and compression cases.

7.2.9. If material property data is *provided* by the instructor, predict the value of *W* that will cause failure.

7.2.10. Report the actual failure load and failure location of the structure at the design demonstration. Discuss the reason(s) for failure. (this is the only section that needs significant modification after the demonstration).

7.2.11. **Costs**, in terms of:

7.2.11.1. **Material used**: (1) total length of basswood used, (2) number of gussets used, and (1) total number of truss

members (a member is defined as a piece of basswood (or part of a piece) that connects two joints);

Include cross-bracing/cross-beams in the cost of the bridge.

7.2.11.2. **Financial Costs, assuming:** (1) each inch of the 3/32″×3/32″ basswood costs $1,000, and (2) each gusset costs $6,000.

7.2.12. Summary and Recommendations.

7.2.13. Appendices: drawings, calculations, design notes, all draft sketches, etc.

7.3. Organize your report into logical and *numbered* sections that can be clearly identified. Headings <u>should</u> include:

- **1. Introduction** – Introduce the purpose/goals/objectives of the design.
- **2 Design** – Describe the evolution of design(s), and why the final design was selected. Include a description and drawings of the final design.

Do not write: "we (A and B) met at A's house, and chose B's design… then C showed up late, but had a cool design and we decided to go with that".

Assume you are writing a professional report that will be read by your boss, other engineers, customers, etc. Write: "The team first considered a Jorstad Truss. However, this truss was not selected due to… Design II was selected, but after analysis, it was decided to modify the truss so that… ."

- **3 Analysis** – Provide a summary of forces acting in truss members, clearing indicating tension and compression. A table is a good way to do this (but do not forget to include a figure with joints to accompany the table); alternatively, the forces can be written directly on a scale drawing of the truss.

  Detailed work/calculations should be included in an appendix.
- **4 Prediction and Results** – Report ("predict") which member was expected to fail. Report the actual results (maximum load, load efficiency) from the demonstration.
- **5 Costs** – Report "costs" in terms of: total basswood length; number of gussets used, and number of members (a member is defined as being between two joints). Also include the dollar amount based on the assumptions listed above. Tables are a good way to present this information.
- **6 Summary** – discussion of results, conclusions, recommendations for future bridges/teams, etc.
- **7 Appendix** – drawings, calculations, draft sketches, etc.

8. GROUP SELF-EVALUATION

8.1. Each **individual** will submit a <u>confidential</u> and <u>individual</u> <u>evaluation</u> of his/her group and its members, due at **6:00pm, Thurs., Dec. 14, 2017.** Evaluation forms will be made available on the course website and/or in class.

9. GRADING

Grade for the project will be based on the following schedule:

9.1. **<u>Team Score</u>**

9.1.1.	*Design of Bridge* (Drawing/Construction)	20%
9.1.2.	*Analysis/Report*	50%
9.1.3.	*Team Bonus**	
	- Strongest Bridge	20%*
	- Most Efficient Bridge (Load/Weight)	20%*
	- Most Cost-Efficient Bridge	20%*

*No team may receive more than 20% bonus.

9.2. **<u>Individual Score</u>. Do your fair share.**

9.2.1.	*Based on Team Self- Evaluations*	30%

10. FIGURES

See page 6 for additional figures.

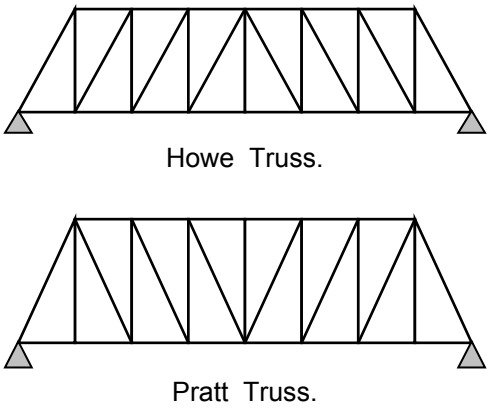

Figure 1: Howe and Pratt Bridge Trusses.

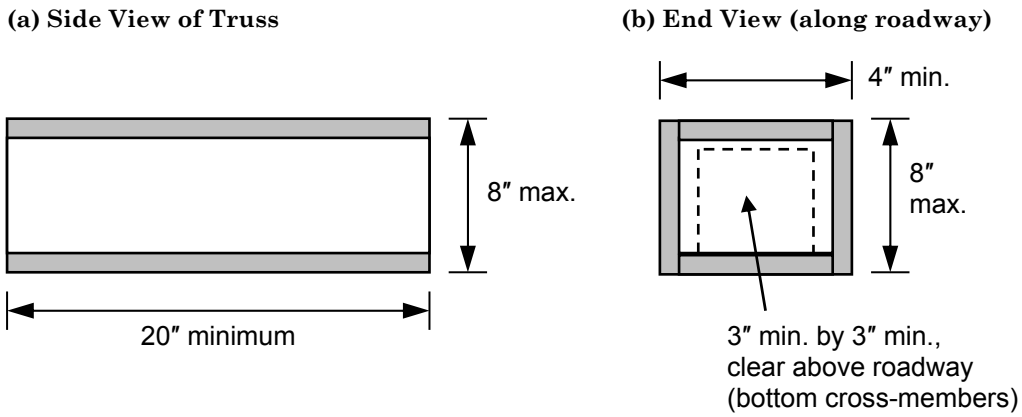

Figure 2: Bridge Dimensions. Not to scale.

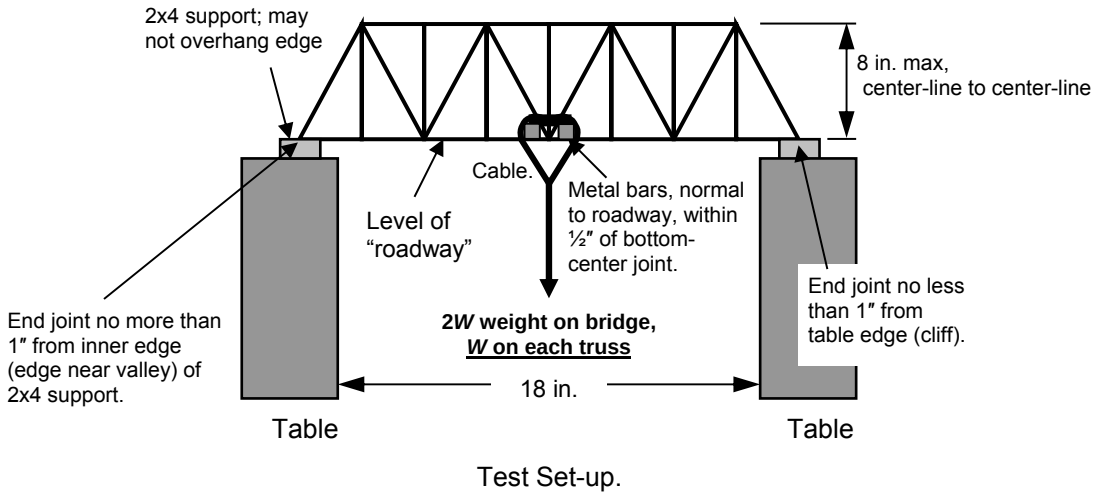

Figure 3: Test set-up. Side view of bridge. Not to scale.

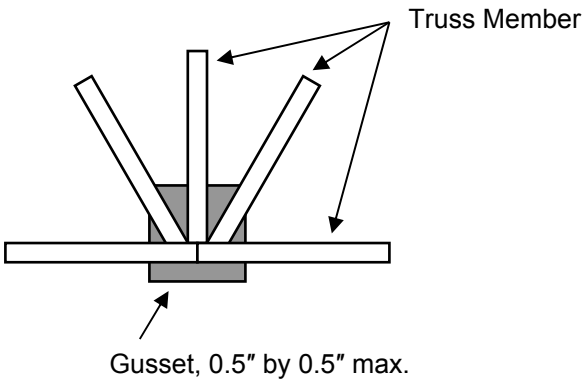

Figure 4: Typical joint with gusset. Not to scale (Gusset shown at maximum size).

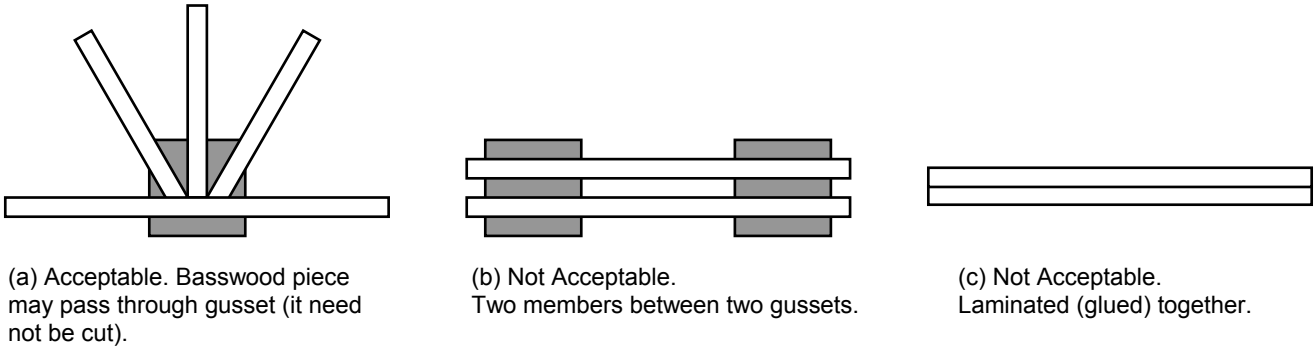

Figure 5: Acceptable and unacceptable construction techniques. (a) A piece of basswood may pass through a gusset (the horizontal member in the figure). (b) No more than one member may connect two joints. (c) Members may not be laminated.